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AD#: TITLE:

DEVELOPMENT OF A HIGH TEMPERATURE SINGLE IMPACT RAIN EROSION TEST CAPABILITY

by

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ABSTRACT

A single impact rain erosion test capability has been developed to obtain data on fiber loaded Teflon® (e.g. Duroid®) ablative radome materials at temperatures up to their ablating temperature (~1250 F). This effort was undertaken as a result of the prior inability to (1) obtain experimental data for single water droplet impacts on these materials at temperatures significantly above 400 F at velocities near Mach 5, and (2) identify a solid particle whose behavior is similar to or can be correlated to that of water droplets at all conditions of interest. This test capability allows one to dispense a stream of calibrated discrete water droplets in the path of aerodynamically heated samples on sleds at velocities up to 6000 ft/sec. Also, solid particles placed on nets in the path of other identical samples on the same sled provide craters at the same velocity and temperature for use in the search for a solid whose erosive behavior can be correlated to that of water droplets.

INTRODUCTION

To develop models for predicting the rain erosion behavior of the fiber loaded Teflon ablative radome materials, experimental erosion data are needed with respect to velocity, angle of incidence, temperature, and water droplet size as well as fiber orientation for each ablator. Previous efforts in FY82 to obtain these data were made in Tunnel G at Arnold Engineering Development Center (AEDC) with some success (1). Results from the AEDC tests indicate that mass loss ratio (mass of water impacted - mass of material removed) is independent of water droplet size for the Duroid materials. From these tests and from multiple impact tests on Holloman sleds (2) it was learned, also, that the rain erosion behavior of these ablators is strongly dependent upon material temperature, and that erosion appears to increase approximately one order of magnitude from ambient temperature to the ablating temperature. In the Tunnel G tests, the high acceleration loads of the powder gun launch caused samples that had been heated uniformly before launch to temperature above 400 F to be lost from the sample holder. Thus, to get data on materials heated to temperatures significantly above 400 F, other techniques were required.

Another method for generating erosion data on heated samples is one which involves firing solid particles at stationary samples heated by a radiant or other source. This method lacks validation because a solid particle that behaves like water droplets at all conditions of interest has not been identified. Thus the only currently available potential solutions involve obtaining data on aerodynamically heated samples or validating a solid particle that can be used in the laboratory to simulate water. To do the latter requires doing the former. The use of Holloman sleds to obtain these data was selected as the best means of accomplishing the objectives (3).

WATER DROPLET DISPENSER

Design, fabrication, and calibration of the water droplet dispenser were performed by Holloman Test Track personnel to provide the single water droplet environment specified to meet MICOM test objectives. These objectives required that three streams of 3 mm dia water droplets be dispensed at a rate that would provide the maximum number of impacts on the samples. After evaluating several water droplet dispenser designs, a design was selected that involves vibrating streams of water from one-eighth inch dia nozzles to break them into droplets of 3 mm dia at a rate of 100 drops per sec. A single nozzle prototype was first built and tested for feasibilty. It was found that a simple one-eighth inch dia tube worked better than a converging nozzle. After the desired performance of the prototype was demonstrated, a three tube design was fabricated and calibrated. Calibration with the Knollenberg Probe indicated that water drop size can be controlled such that 95% or more of the liquid water content is contained in droplets from 2.8 to 3.2 mm dia with 90% confidence. The multiple tube arrangement dispenses water droplets at a controlled rate that can provide the sample nearest the dispenser with up to 12 droplet impacts. For the development test, the dispenser tubes were mounted vertically in a plane 45 deg to the sled rail and spaced so that the distance between centers of craters formed from each stream of droplets was three-eighths in. Figure 1 is a view of the dispenser in operation positioned over the track for the test.

TEST MODELS

Evaluation of the MICOM seven tip test vehicle with conical samples (4) revealed the need for a larger sample size to accommodate the five-eighths in. side-to-side motion of the sled. A flat sample shape was selected to simplify evaluation of the craters. A flat sample measuring 5/16" X 2 1/4" X 3 1/4" was designed to be mounted in two faces of a 60 deg wedge (Figure 2). The sample holder overlaps the four edges of the sample and provides exposed sample dimensions of 2" x 3". For the initial test, the test vehicle was oriented (Figure 3) such that the water droplet streams (positioned above the sled rail) would impact four flat samples (two wedges) and one split conical sample. Figure 4 shows samples in the top wedge impacting the streams of water droplets at a velocity of 4200 ft/sec. In addition, seven different types of solid particles were mounted on nets in the path of seven of the eight remaining flat samples. The eighth sample impacted nothing and served as a control.

PARTICLE NETS

An array of six solid particles of each of the seven particle types was suspended in front of the corresponding sample to be impacted. The seven particle materials tested were nylon, teflon, butyrate, ceramic, acetate, polyethylene, and polypropylene with each particle being 3 mm in diameter. These particles were provided by General Research as part of their participation in the effort to identify a solid particle whose erosive behavior can be correlated to that of water droplets. The materials listed were selected from a screening effort at General Research. The particles were suspended on a net of #6-0 (92μ) surgical silk thread that was attached to a one in. thick circular styrofoam frame as shown in Figure 5. The particles were bonded to the net with a minimal amount of Eastman 910 adhesive. The combined mass of the thread and adhesive contributing to crater damage was less than one percent of the solid particle mass.

TEST ARRANGEMENT AND CONDITIONS

The propulsion system used for the development test consisted of three NIKE motors as shown in Figure 6. This combination was used to propel the sled to a peak velocity of approximately 4200 ft/sec in ten seconds. The water droplet dispenser and particle nets were positioned over the track where maximum velocity was expected. Aerodynamic heating of the Duroid samples produced surface temperatures of about 1200 F. The calculated temperature gradient in the samples near time of impact with the water droplets and solid particles is shown in Figure 7 (5).

DEVELOPMENT TEST RESULTS

The development test was highly successful with respect to obtaining good single impact data for both the water droplets and solid particles. Some of the representative craters caused by these impacts are shown in Figure 8. Data obtained from the craters as well as visual inspection revealed that the impact behavior of the solid particles was unlike that of the water droplets for this set of test conditions. This is reflected primarily in the mass loss ratio parameter and/or crater depth of Figure 8. The mean temperature of the material removed for all craters evaluated was approximately 1000 F.

CONCLUSIONS

The test capability developed in this effort provides an excellent means of obtaining single impact rain erosion data at elevated temperatures and velocities near Mach 5. The water droplet dispenser performed very well and provided the desired environment for single water droplet impacts. As designed, the flat sample provided sufficient impact area for the water droplets and simplified crater evaluation. The sample holders received little or no damage and may be used again. Water droplet data from the development test confirm the AEDC and multiple impact sled results which indicate that rain erosion behavior is strongly dependent on material temperature, and that erosion (mass loss ratio)

appears to increase approximately one order of magnitude from room temperature to the ablating temperature. The particle nets provided a good way to suspend and align the solid particles in the path of the test vehicle. By impacting identical samples, the effects of the solid particles can be directly compared to that of water for each set of test conditions. However, more data are required to determine if there exists a solid particle whose behavior is similar to or can be correlated to that of water droplets for all conditions of interest.

REFERENCES

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(2) Burleson, W. G., Letson, K. N., and Reynolds, R. A., Thermal Performance and Rain Erosion Behavior of Duroid Radome Materials for Conical Models on Mach 5 Sleds, US Army Missile Command, Redstone Arsenal, Alabama 35898, 15 September 1983, Technical Report RL-84-2.

(3) Letson, K. N., and Ormsby, P. A., Rain Erosion Sled Tests of Radome Materials at Mach 5, US Army Missile Command, Redstone Arsenal, Alabama 35898, 26 April 1976, Technical Report RL-76-19.

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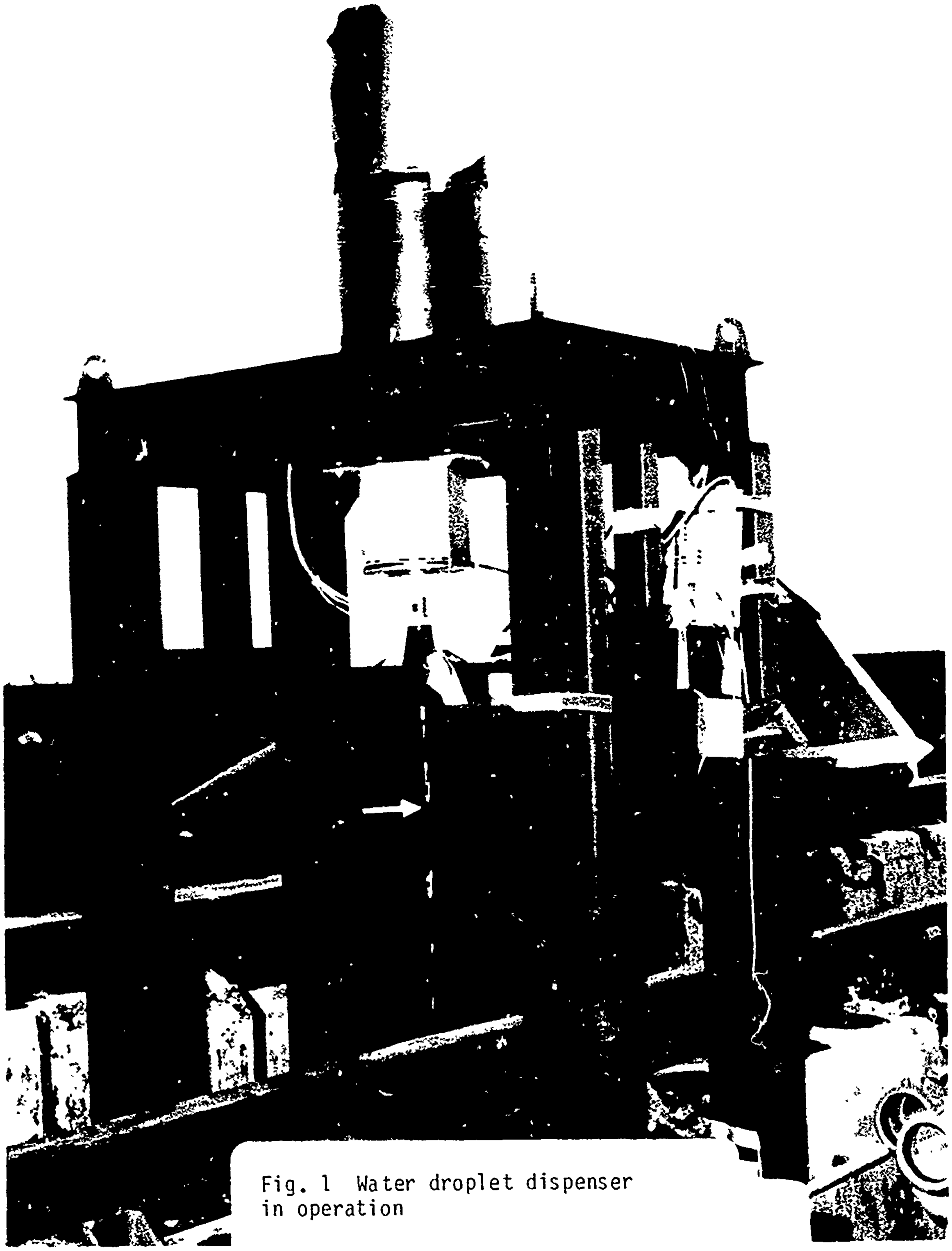


Fig. 1 Water droplet dispenser in operation

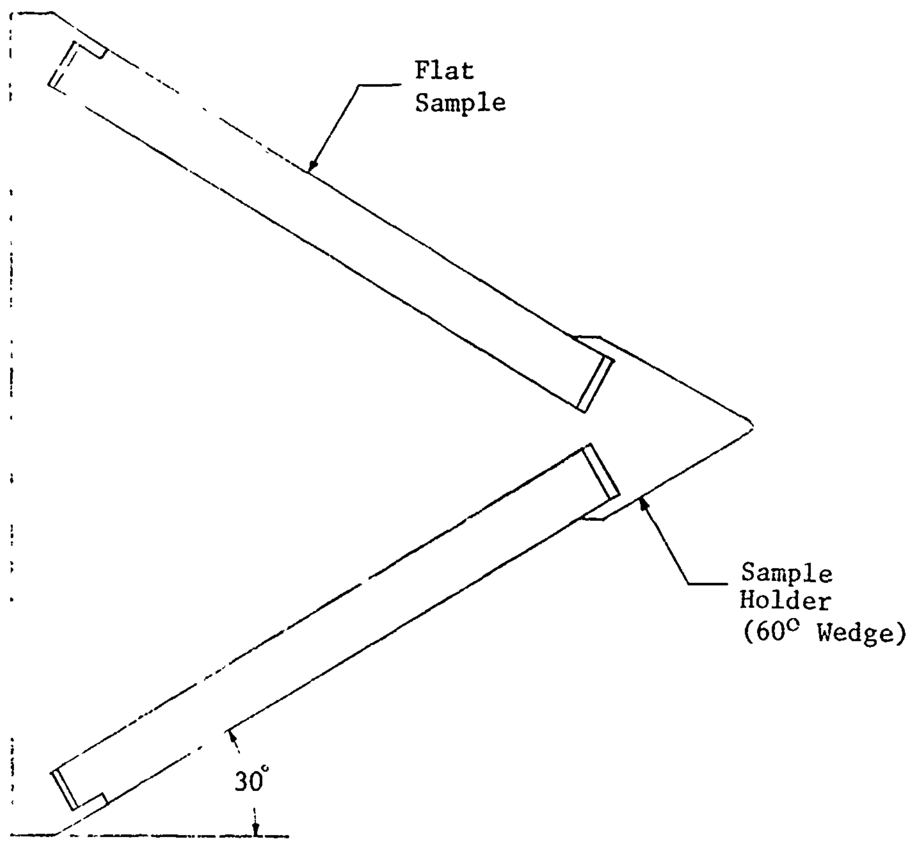


Fig. 2 Side view of sample in holder

Fig. 3 Close up view of sled and sample assemblies

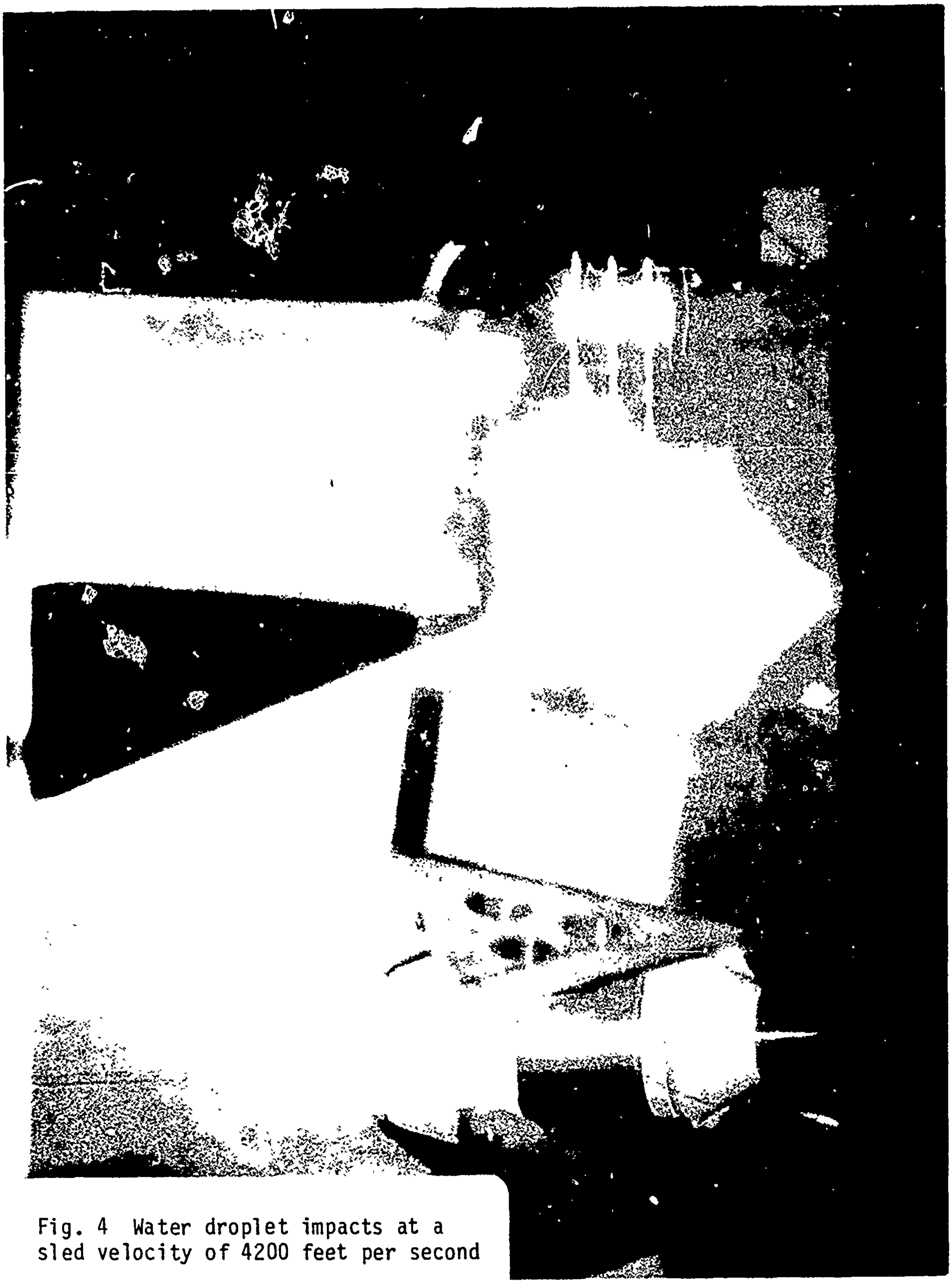


Fig. 4 Water droplet impacts at a sled velocity of 4200 feet per second

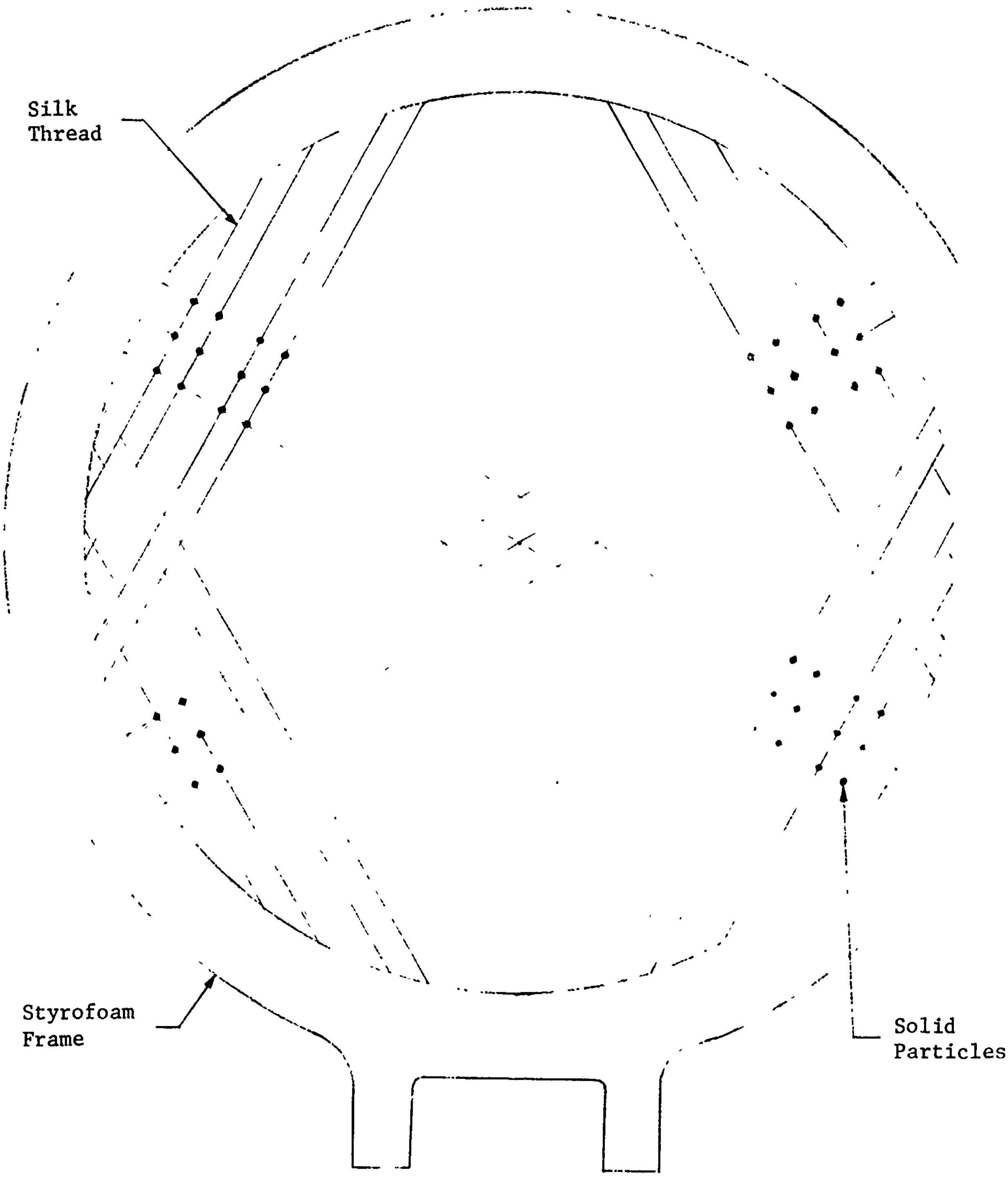


Fig. 5 Particle net assembly

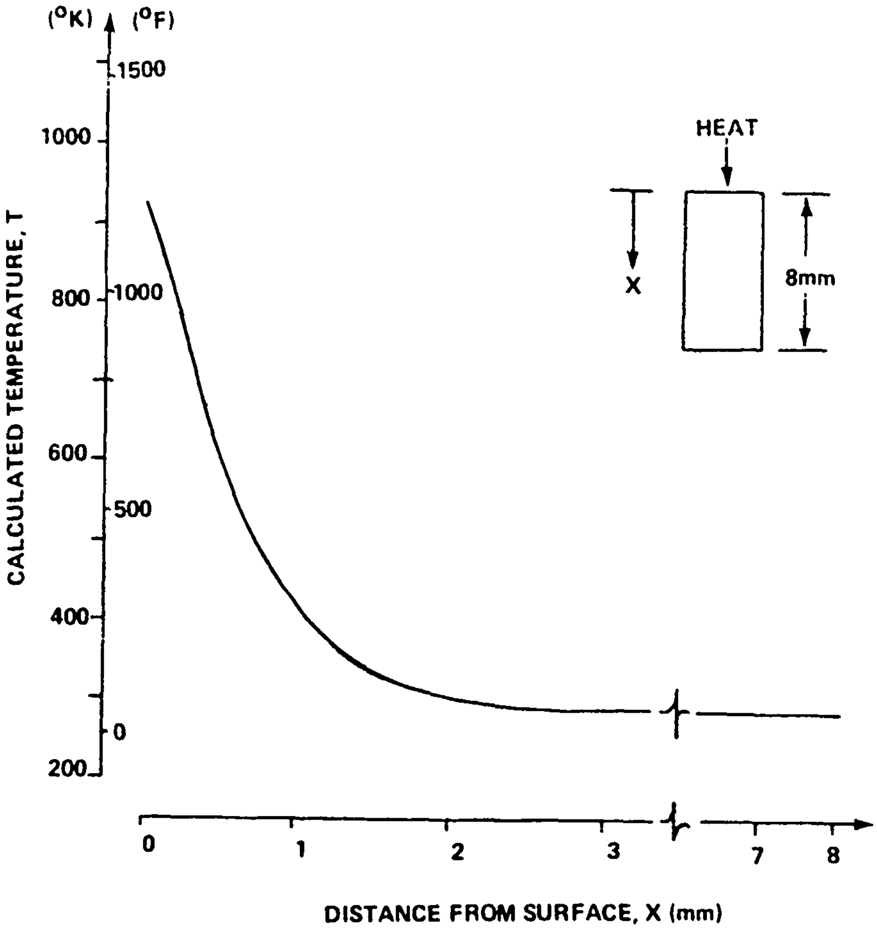


Fig. 6 Temperature gradient of Duroid samples at time of water droplet and solid particle impacts

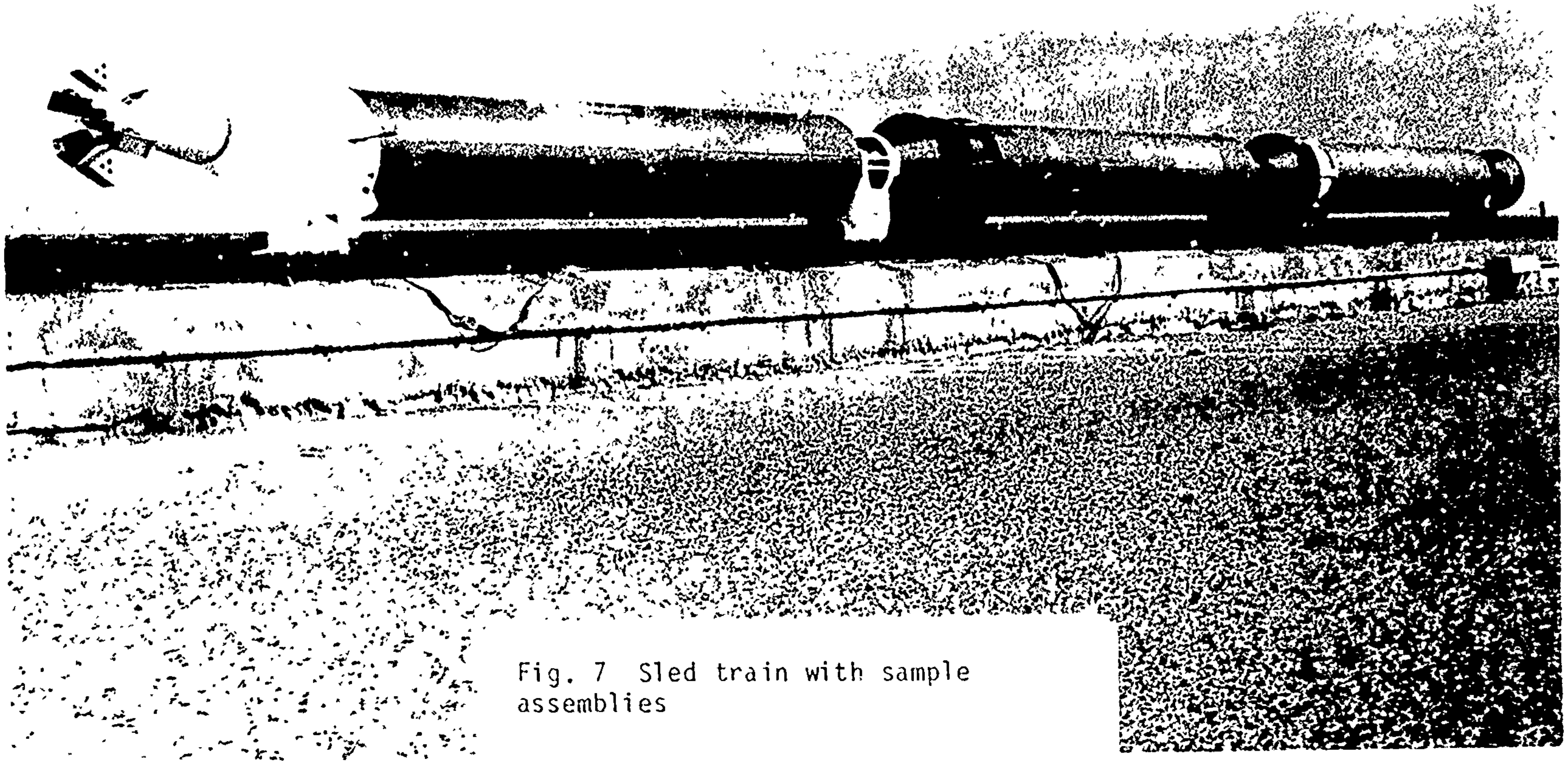


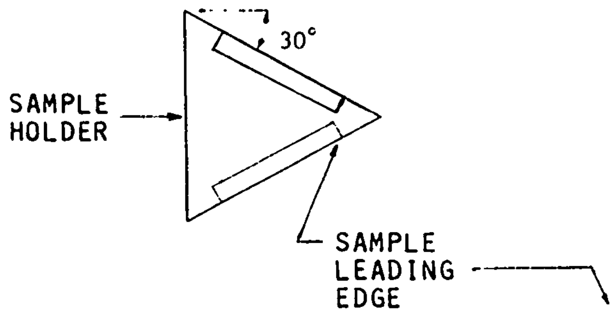
Fig. 7 Sled train with sample assemblies

Fig. 8 **MICOM ABLATIVE RADOME MATERIAL SINGLE IMPACT RESULTS**

CRATERS CAUSED BY 3MM FREE FALLING WATER DROPLETS AND SUSPENDED SOLID PARTICLES AT A SLED VELOCITY OF 4200 FEET PER SECOND.

PARTICLE IMPACTED:	POLYETHYLENE	WATER	NYLON
MAX. CRATER DEPTH (IN.):	.018	.020	.027
MASS LOSS RATIO (MASS REMOVED/MASS IMPACTED)	1.6	2.0	1.4

MATERIAL IMPACTED (ALL): RT/DUROID 5650M (PRESENT PII RADOME MATERIAL)



	BUTYRATE	TEFLON	POLYPROPYLENE
	.022	.050	.023
	1.5	2.1	1.7